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(54) A switching circuit

(57) A switching circuit has a load current path which comprises a series arrangement of a Thyristor (THY1) and a transistor (TR1). The gate electrode of the Thyristor (THY1) and the gate or base electrode of the transistor (TR1) are coupled with a common switching signal input. This arrangement enables efficient turn-off of the thyristor.

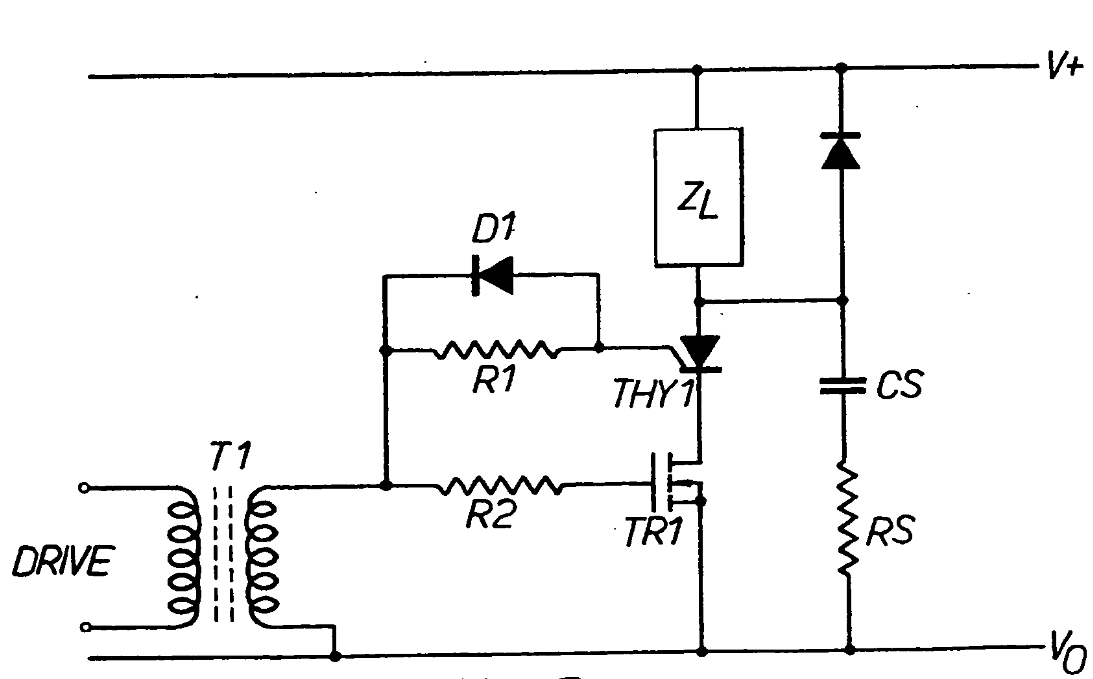

FIG. 2.

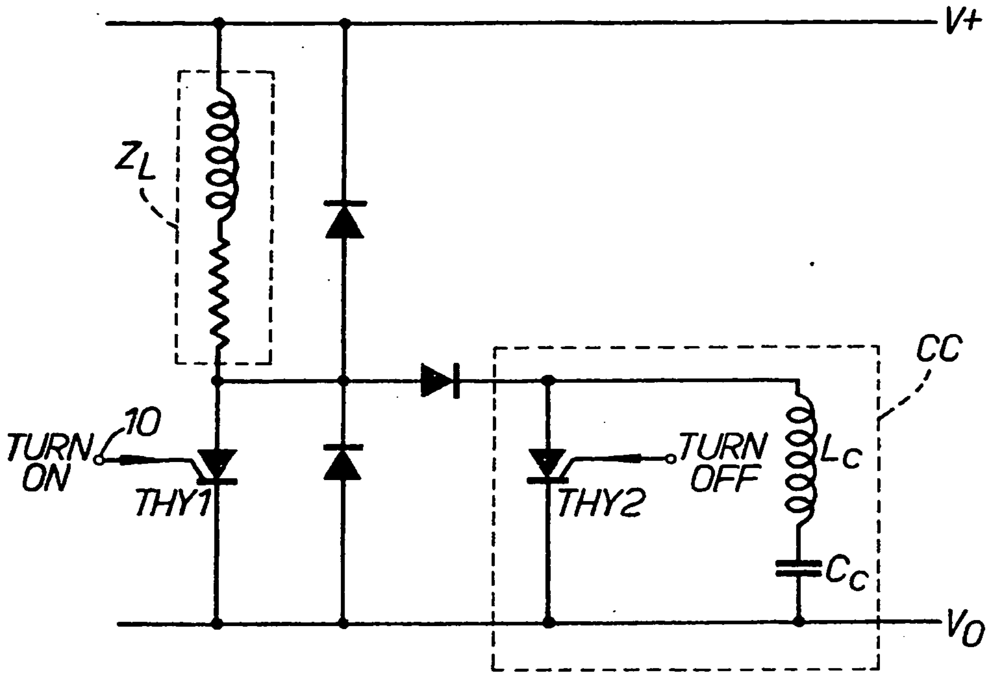
V+
ZL
CC
10
TURN ON
THY1
THY2
TURN OFF
Lc
Cc
Vo

FIG. 1.

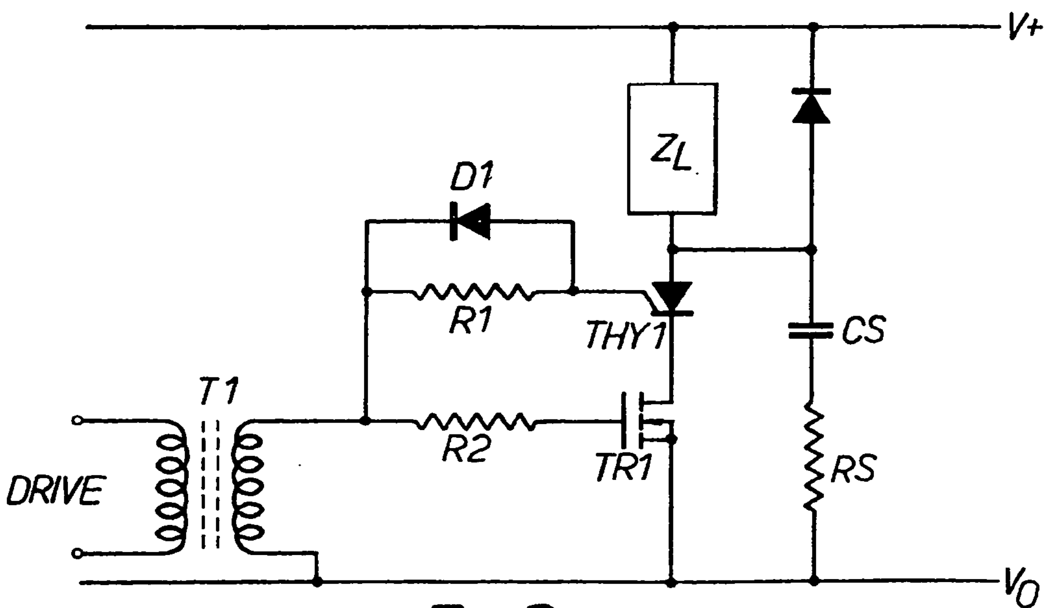
V+
ZL
D1
R1
THY1
CS
T1
DRIVE
R2
TR1
RS
Vo

FIG. 2.

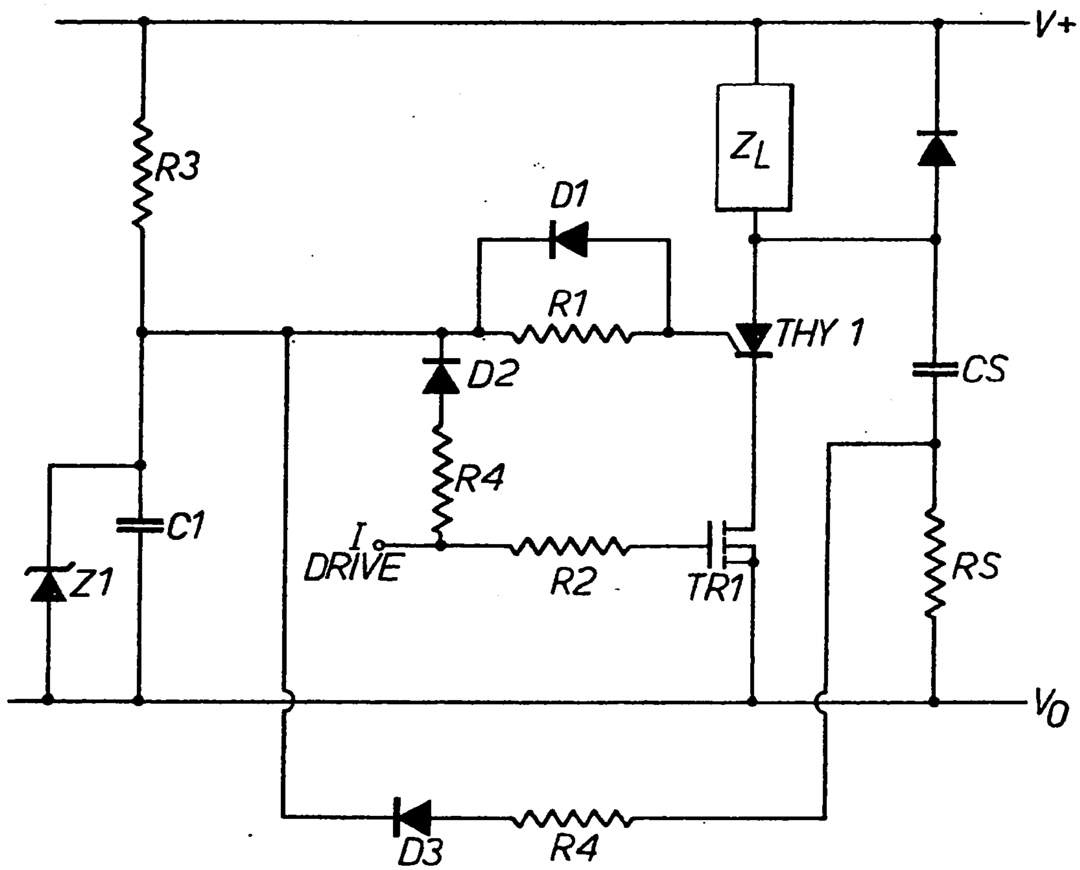

FIG. 3.

SPECIFICATION

A switching circuit

This invention relates to a switching circuit and more particularly to a circuit including a thyristor.

The turn on of a thyristor device is easily effected by gate control voltage but as is well known the switching off cannot be effected merely by varying the gate voltage. In known thyristor switching circuits switch off is effected by means of commutation circuits and these tend to be both bulky and result in power loss thereby making the switching circuit inefficient. Such inefficiency is of particular concern in application of thyristors in high power d.c. to a.c. convertors.

This invention seeks to provide a switching circuit improved efficiency.

According to the invention there is provided a switching circuit in which the load current path comprises a series arrangement of a thyristor and a transistor, wherein the gate electrode of the thyristor and the gate or base electrode of the transistor are coupled with a common switching signal input.

The series arrangement may be shunted by a slow rise circuit which may comprise a capacitor and resistor or an inductor and a resistor connected in series.

The effeciency of the switch may be further improved by providing a biasing circuit for the gate electrode of the thyristor, which biasing circuit comprises a resistor in series with a capacitor, coupled between power supply lines of the circuit, and a zener diode connected in parallel with the capacitor to define the biasing voltage. In such an arrangement the junction between the capacitor and resistor is in electrically conductive connection with the gate electrode of the thyristor and in electrically isolating connection with the base or gate electrode of the transistor via an isolating connection including a reverse bias diode. The arrangement improves the efficiency during rapid repetative switching operation in that during turn off of the thyristor the anode current is diverted out through the gate into the capacitor to provide storage power to aid switch on by subsequent switch on pulse.

A further improvement in efficiency is possible by providing a feedback path in which the voltage developed across the resistor of the slow rise circuit is fed back to boost the charge on the capacitor of the biasing circuit.

In order that the invention and its various other preferred features may be understood more easily, embodiments thereof will now be described, by way of example only, with reference to the drawings in which:–

Figure 1 is a circuit diagram of a typical known thyristor power switch with auxilliary commutation,

Figure 2 is a circuit diagram of a thyris– tor switching circuit constructed in accordance with the invention, and

Figure 3 is another embodiment of thyristor switching circuit constructed in accordance with the invention and including means for improving the switching efficiency.

The known circuit of Figure 1 comprises a main switching thyristor THY1 connected in series with a load Z_L between d.c. supply lines V+ and VO. The gate electrode of the thyristor is connected to an input 10 for receiving a positive pulse or voltage for turning the thyristor on. To effect turn off of the thyristor, an auxilliary commutation circuit is required and the components required for this are both bulky and introduce power losses. The commutation circuit Cc comprises an inductor Lc in series with a capacitor Cc which is shunted by a commutating thyristor THY2. Considerable drive power is required to switch on both the main thyristor THY1 and commutating thyristor THY2.

In order to overcome these difficulties, the cascode connection of thyristor and transistor (in this case a MOSFET) is employed as shown in Figure 2. In this arrangement the source electrode of the MOSFET TR1 is connected to the VO voltage terminal, the drain electrode is connected to the cathode electrode of the thyristor THY1 whilst the anode electrode of the thyristor THY1 is connected via a load Z_L to a V+ line. Connected in parallel with the thyristor and transistor circuit there is a series circuit of resistor RS and capacitor CS these two components forming a known slow rise circuit. The load Z_L is shunted via a protection diode. The gate electrode of transistor TR1 is connected via a resistor R2 to the secondary of a transformer T1 which secondary is also connected via a resistor R1 to the gate electrode of the thyristor THY1 the resistor R1 is shunted by a diode D1 the anode of which is connected to the thyristor end of the resistor. The primary winding of the transformer forms the drive input for the switching circuit and is fed with positive and negative pulses for switching the circuit on or off respectively.

The circuit operation is as follows: to turn thyristor THY1 on, a positive pulse is applied to TR1 gate and THY1 gate, via the isolating transformer T1. The MOSFET TR1 rapidly turns on allowing the thyristor to turn on in the normal way.

To turn the thyristor off a negative pulse is applied via the transformer T1. TR1 will turn off rapidly (typically less than 100 ns) and the anode current in THY1 will be diverted out through the gate. Under these circumstances, THY1 comes out of saturation and rapidly turns off. TR1 is preferably a low voltage, high current, low on resistance device for good efficiency.

The circuit of Figure 3 is a modification of the circuit of Figure 2 and similar components have been given similar reference designations. Only the additional circuitry will be described. The circuit of Figure 3 is arranged to be directly driven at an input I. This input is coupled to the transistor TR1 via the resistor R2 and is also coupled to the resistor R1 which feeds the gate electrode of thyristor THY1 via a resistor R4 in series with a diode D2, the diode configuration being so as to permit passage of positive input vol-

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

tages or pulses. The junction of resistor R1 and diode D2 is connected to a thyristor biased circuit which comprises a capacitor C1 connected to the VO line and provided with a parallel connected zener diode Z1. The capacitor C1 is fed from the V+ line by a resistor R3. A feedback path is provided from the junction of the resistor RS and capacitor Cs to the junction of the capacitor C1 and resistor R3 which feedback path includes a resistor R4 and diode D3 the cathode of which is connected to the junction of C1/R3.

Drive efficiency is improved in the circuit of Figure 3 by recovering some of the turn off energy from the thyristor. The gate current of the thyristor on turn off is fed to capacitor C1. The capacitor voltage is limited by Z1. The resistor R3 provides an initial charge to capacitor C1. For short pulse drives or operation at longer intervals with the thyristor current above the holding value, it is only necessary to supply enough drive energy to switch the MOSFET TR1. The slow rise circuit CSRS is also used to boost the available drive energy in capacitor C1 by the feedback path via resistor R4 and diode D3. This additional boost would be dispensed with where fast rising voltage is required at the thyristor anode.

Typical voltages employed are for the V+ line 1.5 Kv and the drive voltage to transistor TR1 is preferably arranged to operate at its optium switching voltage typically 13 volts. The thyristor and MOSFET can be of a high current rating type e.g. 40 amps.

Higher efficiency can be provided by replacing resistors RS and R4 with inductors. Although transistor TR1 is preferably a MOSFET type it will be appreciated that a bipolar transistor could be used instead, but the MOSFET does have the special advantages of low on resistance, ease of drive and good efficiency. Due to the positive switch off action by the transistor re-triggering of the thyristor due to rapid change of anode voltage with time is eliminated.

The switching circuit is particularly suitable for use in driving d.c. to a.c. invertors e.g. bridge invertors and has application in high power sonar transmitters. However the circuit is applicable in any power switching application.

CLAIMS

1. A switching circuit in which the load current path comprises a series arrangement of a thyristor and a transistor, wherein the gate electrode of the thyristor and the gate or base electrode of the transistor are coupled with a common switching signal input.

2. A switching circuit as claimed in claim 1, wherein the series arrangement is shunted by a slow rise circuit comprising a capacitor and a resistor connected in series.

3. A switching circuit as claimed in claim 1, wherein the series arrangement is shunted by a slow rise circuit comprising an inductor and a capacitor connected in deries.

4. A switching circuit as claimed in any one of the preceding claims connected to a load wherein the load is shunted by a diode in reverse biased configuration.

5. A switching circuit as claimed in any one of the preceding claims, wherein the gate or base electrode of the transistor is coupled with the signal input via a resistor, and the gate electrode of the thyristor is coupled with the signal input via a parallel arrangement of a diode and a resistor, the diode being arranged to be forward biased by a switch off pulse.

6. A switching circuit as claimed in any one of the preceding claims, wherein the common switching signal input is coupled to the secondary of a transformer for providing input signals.

7. A switching circuit as claimed in any one of claims 1 to 5, which includes a biasing circuit for the gate electrode of the thyristor, which biasing circuit comprises a resistor in series with a capacitor, coupled between power supply lines of the circuit, and a zener diode connected in parallel with the capacitor to define the biasing voltage, and the junction between the capacitor and resistor is in electrically conductive connection with the gate electrode of the thyristor and is electrically isolated from the base or gate electrode of the transistor by a connection including a reverse biased diode.

8. A switching circuit as claimed in claim 7, wherein the isolating connection includes a series resistor.

9. A switching circuit as claimed in claim 7, wherein the isolating connection includes a series inductor.

10. A switching circuit as claimed in claim 7, 8 or 9 when dependent from claim 2, wherein the voltage developed across the resistor of the slow rise circuit is fed back to boost the charge on the capacitor of the biasing circuit.

11. A switching circuit as claimed in claim 7, 8 or 9 when dependent upon claim 3, wherein the voltage developed across the inductor of the slow rise circuit is fed back to boost the charge on the capacitor of the biasing circuit.

12. A switching circuit as claimed in claim 10 or 11, wherein the feedback path includes a diode which is arranged to be forward biased to effect the feedback to the biasing circuit.

13. A switching circuit as claimed in any one of the preceding claims, wherein the transistor is a MOSFET.

14. A switching circuit substantially as described herein with reference to, or as illustrated in Figure 2 or 3 of the drawings.

15. A d.c. to a.c. inverter including a switching circuit as claimed in any one of claims 1 to 14.

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